Review

The Effectiveness and Cost Effectiveness of Public-Access Defibrillation

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ABSTRACT

Many sudden cardiac deaths are due to ventricular fibrillation (VF). The use of defibrillators in hospitals or by outpatient emergency medical services (EMS) personnel can save many cardiac-arrest victims. Automated external defibrillators (AEDs) permit defibrillation by trained first responders and laypersons. AEDs are available at most public venues, and vast sums of money are spent installing and maintaining these devices. AEDs have been evaluated in a variety of public and private settings. AEDs accurately identify malignant ventricular tachyarrhythmias and frequently result in successful defibrillation. Prompt application of an AED shows a greater number of patients in VF compared with initial rhythms documented by later-arriving EMS personnel. Survival is greatest when the AED is placed within 3 to 5 minutes of a witnessed collapse. Community-based studies show increased cardiac-arrest survival when first responders are equipped with AEDs rather than waiting for paramedics to defibrillate. Wide dissemination of AEDs throughout a community increases survival from cardiac arrest when the AED is used; however, the AEDs are utilized in a very small percentage of all out-of-hospital cardiac arrests. AEDs save very few lives in residential units such as private homes or apartment complexes. AEDs are cost effective at sites where there is a high density of both potential victims and resuscitators. Placement at golf courses, health clubs, and similar venues is not cost effective; however, the visible devices are good for public awareness of the problem of sudden cardiac death and provide reassurance to patrons.

Introduction

Sudden cardiac death is a major problem resulting in unexpected loss of life in many otherwise high-functioning persons. The introduction of ventricular defibrillation in the hospital setting in the 1950s permitted resuscitation of persons with in-hospital ventricular fibrillation (VF) cardiac arrest and resulted in the development of the critical care unit for the treatment of acute myocardial infarction (AMI).[1] The migration of defibrillators to the outpatient setting and their use by emergency medical services (EMS) personnel,[2] coupled with widespread teaching of cardiopulmonary resuscitation (CPR) to the lay public, allowed survival of some patients with out-of-hospital cardiac arrest. Implantable cardioverter defibrillators (ICDs) improve survival in cardiac-arrest victims but require that patients be identified as high risk prior to their cardiac arrest.[3,4,5] Automated external defibrillators (AEDs) are currently on the walls of public venues, and many patients ask if they should purchase an AED for their home. This review examines available evidence as to whether AEDs save lives and the cost of saving a life with an AED.

Rationale for AEDs

Approximately 250 000 persons die of out-of-hospital cardiac arrest each year in the United States, and many more die worldwide.[6] At the time the first electrocardiography (ECG) is recorded, approximately 40% of cardiac-arrest victims are in VF, and more have VF at the time of collapse. Survival falls by 7% to 10% per minute until defibrillation is applied for a witnessed cardiac arrest if no CPR is given, and by 3% to 4% per minute if bystander CPR is started.[6,7,8] Bystander CPR can double or triple survival from witnessed sudden cardiac arrest at any interval until defibrillation is applied.[9] The American Heart Association identifies 4 links to create a "chain of survival" for VF sudden-cardiac-arrest victims.[10] This includes: (1) early access to the EMS system, (2) early bystander CPR, (3) early delivery of the defibrillation shock, and (4) early advanced cardiac life support. AEDs permit bystanders to perform 3 of the 4 links.

General Properties of AEDs

Current AEDs provide extremely accurate automatic recognition of life-threatening ventricular tachyarrhythmias. They offer visual and auditory instructions and warnings and can be utilized by persons with little or no training. Most provide ECG documentation of the rhythms prior to and after defibrillation. They have self-test and power-indicator alarms and a finite battery life. AEDs cost from $1300 to $3000, depending upon the features of the device. AEDs require human monitoring and training programs, and some installations automatically activate the EMS system when taken out of their containers.

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Definition of "Public-Access Defibrillation"

There is no strict definition of "public-access defibrillation." In its purest sense, this is defibrillation using an AED by persons other than trained public-safety personnel such as police, firefighters, or security officers. Public access defibrillation could be performed by laypersons, randomly passing medical personnel, athletic or golf club employees, or ushers at sporting events. Most reports on AED use do not follow a pure definition of public-access defibrillation. In this review we evaluate the efficacy of AEDs regardless of who applies the device.

AEDs on Aircraft and in Airports

In 1991, the airline Qantas placed AEDs at major airports in Australia and on all international aircraft.[11] Ground and flight crews were trained in CPR, and selected persons were trained in the use of the AED. AED use was evaluated over 65 months involving >200 000 flight segments and 31 000 000 passengers. The AED was used 109 times: 63 times to monitor an ill patient and 46 times for a cardiac arrest (27 on aircraft and 19 in the terminal). Arrests were witnessed in all 19 cases in the terminal and in only 16 of 27 (59%) cases on the aircraft. Presumably the nonwitnessed arrest victims were thought to be sleeping or in the restroom on a long international flight. None of the 23 patients with bradyarrhythmias survived. When VF was the initial rhythm, 21 of 23 patients were successfully defibrillated. Only 6 (2 on the aircraft and 4 at the terminal) survived to hospital discharge. Flight diversion due to medical emergencies is expensive for airlines and disruptive to passengers. Qantas made an appropriate decision to not divert planes if the documented rhythm of cardiac arrest was asystole or pulseless idioventricular rhythm. This provided substantial cost savings to the airline to partially offset the cost of the AED program.

In 1997, American Airlines equipped planes with AEDs and trained flight attendants in their use. On 627 956 flights from June 1, 1997, to July 15, 1999, involving 71 000 000 passengers,[12] the AED was used every 3228 flights, and death or resuscitation from cardiac arrest occurred every 21 654 flights. The AEDs were used 200 times (9 at the gate and 191 on the aircraft). AEDs were used 101 times to monitor an ill passenger and 99 times for loss of consciousness. Fifteen patients had VF, and a shock was given by the AED. Six of the 11 patients with VF on the plane (55%) and none of the 4 at the gate were discharged home. An additional 20 patients died, 14 with agonal rhythms and 6 with an initially stable rhythm; none received an AED shock. Overall, 17% of cardiac-arrest victims were discharged alive from the hospital.

Airports provide an excellent venue for dissemination of AEDs. AEDs that automatically activate the EMS system were placed within a 60- to 90-second walk of all passenger areas at O'Hare, Midway, and Meigs Field airports in Chicago, IL.[13] AED use by bystanders was promoted in public-service videos in waiting areas, and in pamphlets and media reports. More than 100 000 000 passengers pass through these airports annually. During the evaluation period, 18 patients experienced witnessed cardiac arrest. The average age was 67.8 years, and 94.4% were male. CPR was administered prior to the AED shock in 94.4% of patients. Seven of 18 (38.8%) uses of the AED were by persons with no prior training in the use of an AED, although 3 of the 7 bystanders were physicians. Sixteen of the 18 (89.9%) uses of the AED were by good Samaritans. Eleven patients (61.1%) survived to a neurologically intact hospital discharge. Time to application of the AED shock was important for survival. The AED was used <5 minutes after collapse in 12 patients, and 75% survived; whereas only 2 of 6 (33%) survived when AED shocks were delivered >5 minutes after collapse. Even in a crowded public place with many potential victims and bystanders, there is a very limited time window during which an AED can be utilized successfully.

Use of AEDs in Casinos

The gaming floors of casinos offer a unique opportunity to evaluate the use of AEDs. On casino floors, every customer is within sight of a security guard and there is widespread camera surveillance. Beginning in March 1997, a 32-casino resuscitation program was started.[14] AEDs were stationed within minutes of every location where gamblers were present. One security officer proceeded to the victim to initiate CPR while another obtained the AED. Resuscitation continued until the patient had a pulse and respiration, or until EMS personnel arrived.

The AED was utilized for 148 cardiac arrests. The initial documented rhythm was VF in 105 cases (71%), asystole in 26 (18%), and pulseless electrical activity in 17 (11%). None of the 43 patients with pulseless electrical activity or asystole survived. With VF as the initial rhythm, 56 of 105 patients (53%) survived to hospital discharge. Time to defibrillation was again an important predictor of survival. When the first AED shock was delivered <3 minutes from time of collapse, the hospital discharge survival rate was 74%; it was only 49% when the shock was given >3 minutes after collapse ($P = 0.02$). The casino experience probably represents the gold standard with regard to the most optimistic outcomes one could expect for survival of out-of-hospital cardiac arrest.

Community-Based Evaluation of AEDs

Several studies evaluate the use of AEDs in the general community where the density of cardiac arrests and potential rescuers is lower than in public-venue locations. Seattle, Washington is a leader in training and disseminating EMS personnel to respond promptly to all cardiac emergencies.[2] When AEDs were placed in the hands of first-responder firefighters for treating cardiac arrests, 84

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of 276 (30%) survived to hospital discharge, compared with only 44 of 228 (19%) when firefighters performed CPR and waited for defibrillation by EMS personnel ($P < 0.001$).[15] In a city-wide study, 475 AEDs were placed in the general community and more than 4000 persons trained in both CPR and AED use.[16] During 4 years, EMS personnel were called to 3754 cardiac arrests. Bystanders used the AED in only 50 (1.33%) of the cardiac arrests. Bystander CPR was started in all 50 victims, and 92% of arrests were witnessed. VF was the rhythm in 42 of the 50 patients (84%) at the time of AED placement. The AED was operated by a nurse, medical doctor, or other medically trained person in 26 of the 50 arrests. Lay responders accounted for 18 uses of the AED, police for 4, and unknown persons for 2. Twenty-five of the 50 cardiac-arrest victims survived to hospital discharge. This study suggests that, despite community-based dissemination of AEDs, they are used in only a very small fraction of out-of-hospital cardiac arrests. Nonetheless, in the small number of instances where the AED is used, VF is documented in a high percentage of patients and hospital survival is higher than would be expected without the use of the AED.

A large randomized trial evaluated the efficacy of placing AEDs throughout multiple communities.[17] In 933 North American communities, 19 000 volunteers were trained in CPR alone or CPR plus the use of an AED. Communities were randomly assigned to receive one of these treatment strategies. Eighty-four percent of the AEDs were placed in public facilities and 16% were placed in residential units. The primary outcome was survival to hospital discharge. Over a 3-year span, there were 107 cardiac arrests in the CPR-only communities and 128 in the CPR+AED communities. There was no difference in the initiation of bystander CPR in the 2 treatment arms (62.0% vs 64.8%). AED shocks were delivered by non-EMS personnel in 44 of the 128 (34.4%) cardiac arrests in the CPR+AED community vs only 2 of 107 (1.9%) in the CPR-only community. The interval between the call to EMS and first rhythm assessment was shorter in the AED communities, at 6.0 vs 8.7 minutes ($P < 0.001$). Even though 30% (70 of 235) of the cardiac arrests occurred in residential units, there was only 1 residential unit survivor in each treatment group. In the CPR-only communities 15 of 107 (14%) survived, and in the CPR+AED communities 30 of 128 (23%) survived ($P = 0.03$). More than 90% of the survivors in both groups had normal or only mildly impaired cerebral performance.

These community-based studies show that widespread dissemination of AEDs can save a small number of lives. AED placement in residential units results in little reduction in the mortality from sudden cardiac arrest. Even when AEDs are widely disseminated in public places, they are utilized in only a very small fraction of out-of-hospital cardiac arrests. However, in that small subset, AEDs do seem to improve survival.

Home Use of AEDs to Prevent Sudden Death in Individual High-Risk Patients

A randomized trial evaluated the role of home AED placement in 7001 survivors of anterior-wall MI who were not candidates for ICDs.[18] Patients were randomized at 178 centers in 7 countries to the usual strategy of calling EMS and performing CPR, or using an AED followed by calling EMS and performing CPR. The median patient age was 62 years and 17.4% were female. Q-wave MI had occurred in 64.4%. The median time from infarction to enrollment in this trial was 1.7 years. Spouses were the designated rescuers in 87.8% of cases. Some patients (2.6%) and rescuers (48.8%) worked at a job away from home. Patients spent 1.5 hours a day at home alone and 4 hours away from home. During the trial, 4.2% of AED patients and 4.6% of controls crossed over to ICD therapy. There were 228 deaths from all causes and 78 sudden cardiac deaths in the control group, and 222 deaths from all causes and 82 sudden cardiac deaths in the AED group (P value not significant). A majority of cardiac arrests occurred at home, but only about a third were witnessed. Nineteen patients were resuscitated in each group. This study suggests that for high-risk patients, placement of home AEDs does nothing to alter rate of resuscitation from cardiac arrest.

Cost Effectiveness of AEDs Placed in Public Settings

Several studies examine cost effectiveness of AEDs for saving lives using the standard evaluation of dollars spent per quality year of life saved. Placement of AEDs at sites with high densities of both victims and good Samaritans, such as aircraft, large airports, and casinos result in an average cost per year of life saved of approximately $35 000 to $50 000.[19,20] The cost of saving lives by placing AEDs on aircraft depends upon the size of the aircraft and the training of personnel. Placing AEDs on aircraft with >200 passengers costs approximately $35 000 per year of life saved. Placing AEDs on all aircraft costs an additional $94 700.[20] Since the average cardiac-arrest survivor lives about 5 years following resuscitation, it costs approximately $250 000 to save 1 life. Placing AEDs in large public venues such as shopping malls or sports venues costs approximately $500 000 to more than $2 million per quality year of life saved.[19] Cost of placement at large industrial sites, golf courses, health clubs, and community centers can range from $1 million to $10 million per quality year of life saved. Placement of AEDs at sites where the cost per quality year of life saved is on the lower end of the spectrum is consistent with many medically accepted procedures. Placement at sites costing millions of dollars per quality year of life saved is not consistent with generally accepted expenditure of healthcare dollars. Nonetheless, placement at golf courses, health clubs, and other high-visibility sites is probably good for the overall public awareness of sudden cardiac death.

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Conclusion

Current AEDs are simple to use and safe, and their algorithms are very accurate for detecting ventricular tachycardia and VF. The earlier they are placed on a patient, the higher the percentage of patients that are found to be in treatable VF. The window of opportunity for applying a life-saving defibrillator shock is remarkably short, and delivery beyond 3 to 5 minutes results in dramatically lower rates of successful resuscitation. When these devices are placed in public areas with large numbers of both victims and resuscitators, they are able to increase the yield of survival of out-of-hospital cardiac arrest. AEDs are cost effective only when used in situations where a reasonable number of cardiac arrests are expected to occur, the arrests are likely to be witnessed, and there are enough AEDs available to permit defibrillation within minutes. AEDs have minimal impact when placed widely in the community and have little or no role in saving the life of any single high-risk individual where ICDs are the preferred treatment.

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